Real-time Global Flood Monitoring and Forecasting Using an Enhanced Land Surface Model with Satellite-based and NWP Forcings

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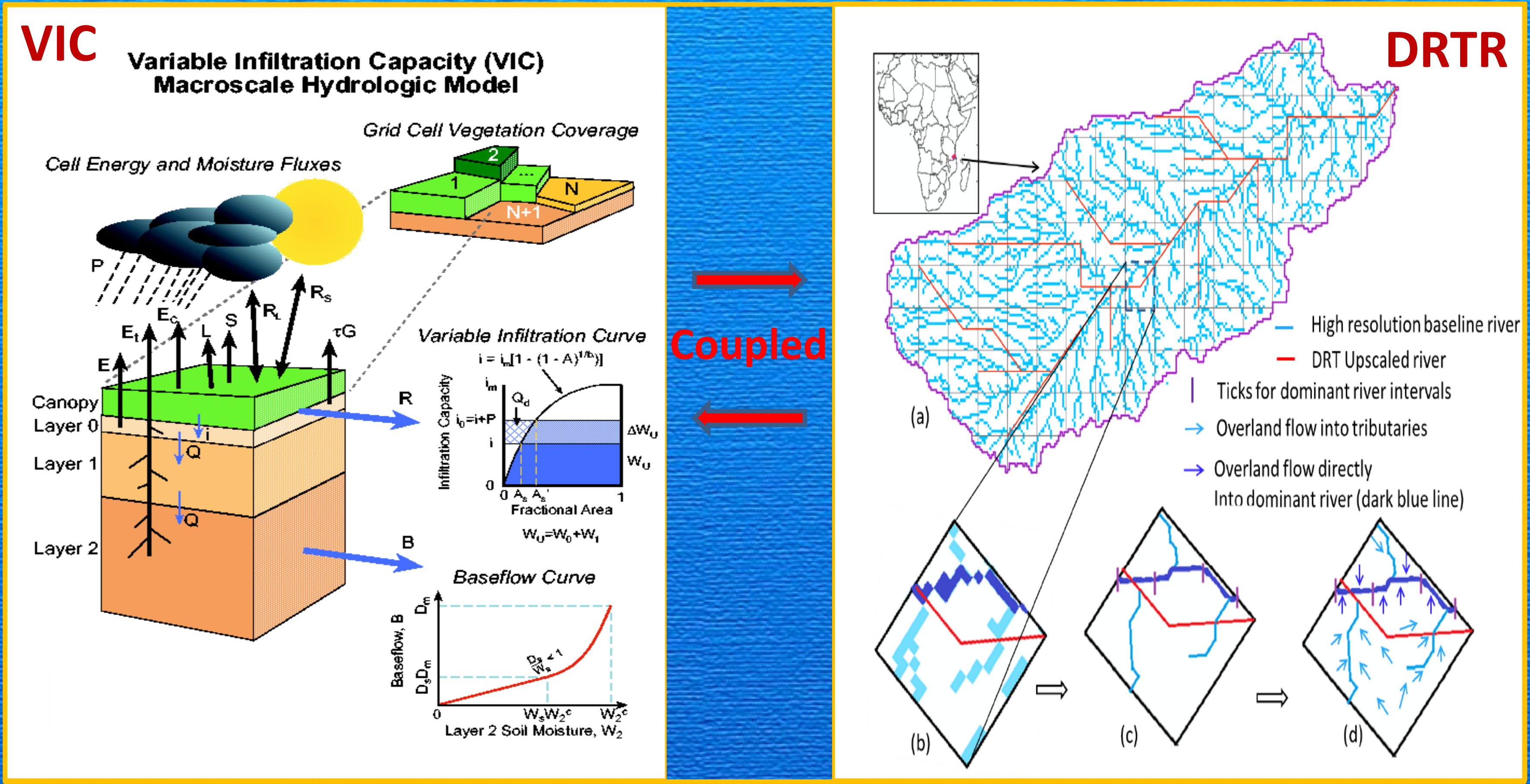
Dominant river tracing-Routing Integrated with VIC Environment (DRIVE) model

(Wu et al., 2011, 2012, 2013 *Water Resources Research*)



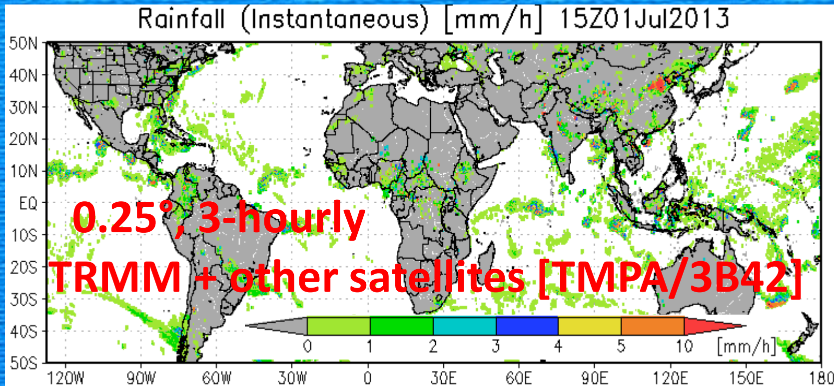
University of Washington

ESSIC, University of Maryland/NASA GSFC

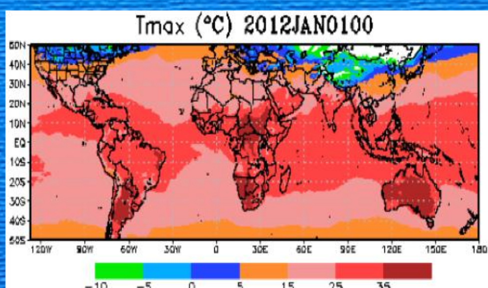
System is running quasi-globally <u>every three hours at 1/8th degree</u>, and routing is also running at <u>1km resolution.</u>

DRIVE model

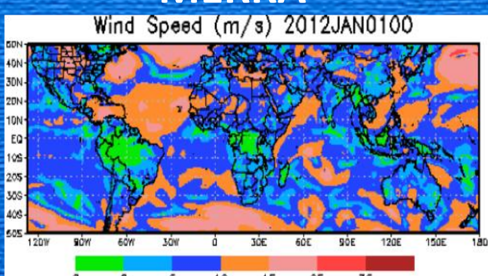
http://flood.umd.edu

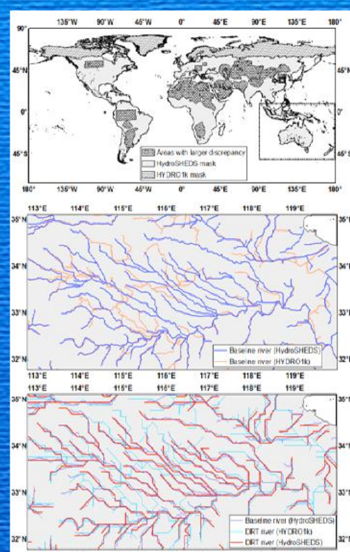


0.25°, 3-hourly
TRMM + other satellites [TMPA/3B42]



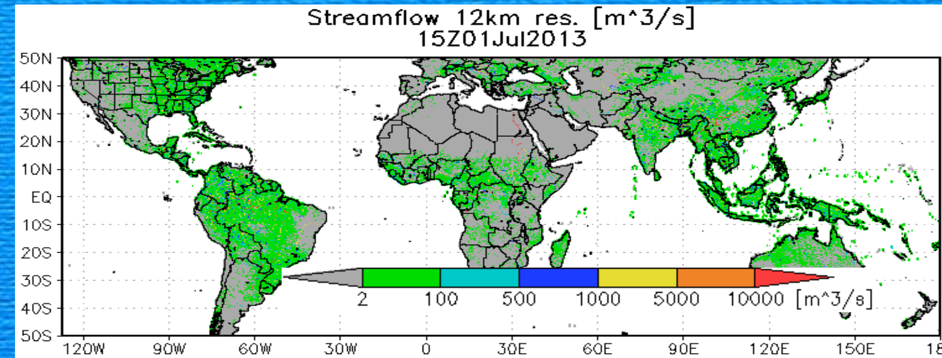
MERRA

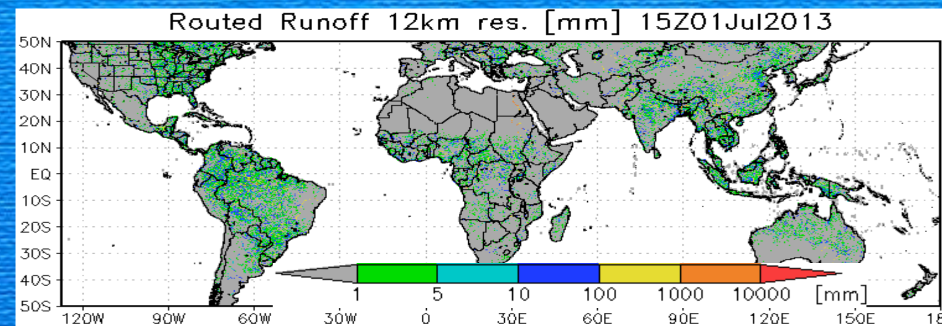


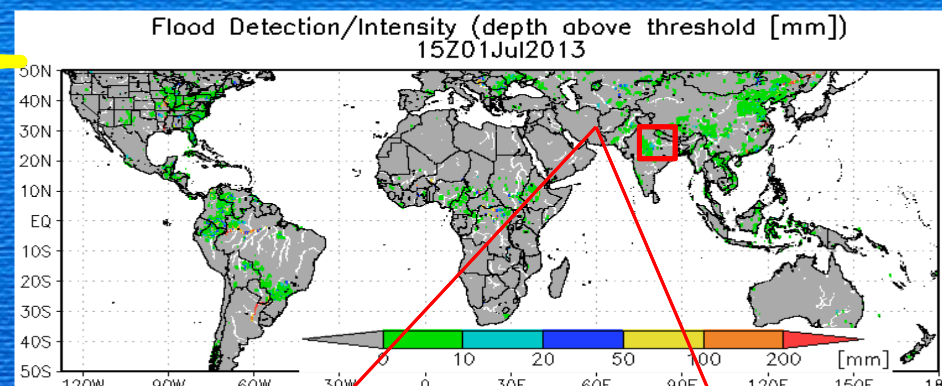


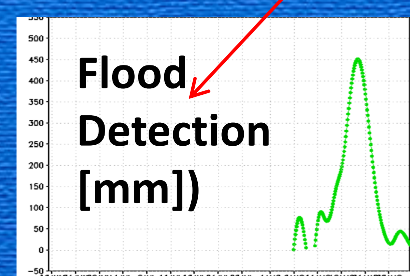
Wu et al., 2012

Soil, Vegetation (Princeton)
DEM (HydroSHEDS)

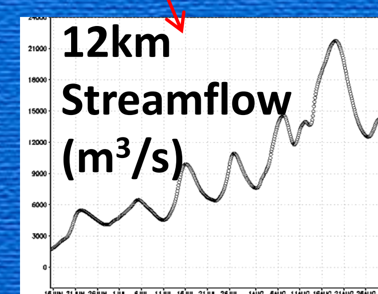








Flood
Detection
[mm])



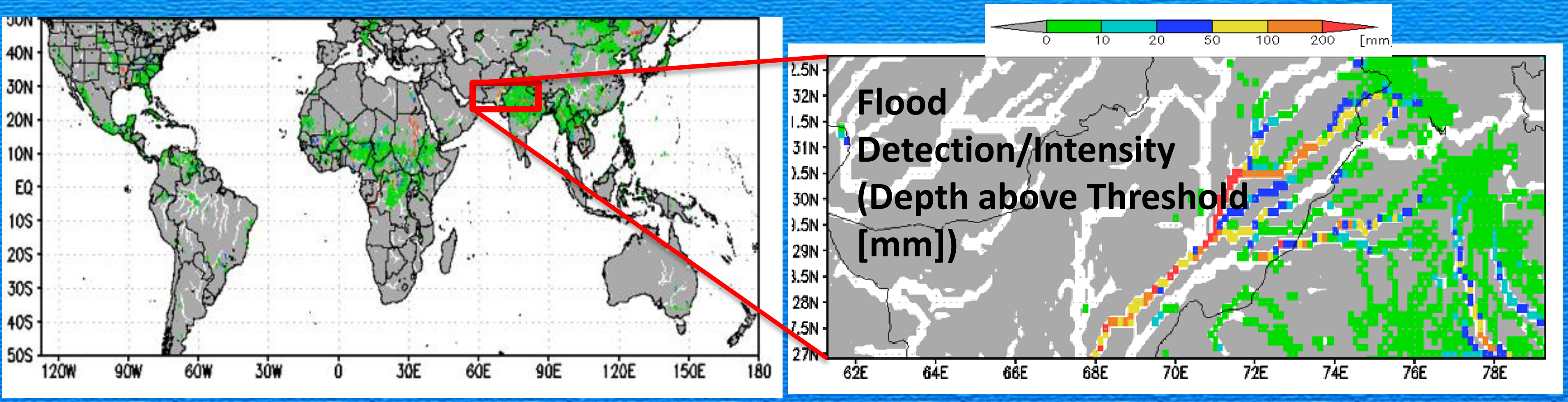
12km
Streamflow
(m^3/s)

Global to Regional Flood Detection

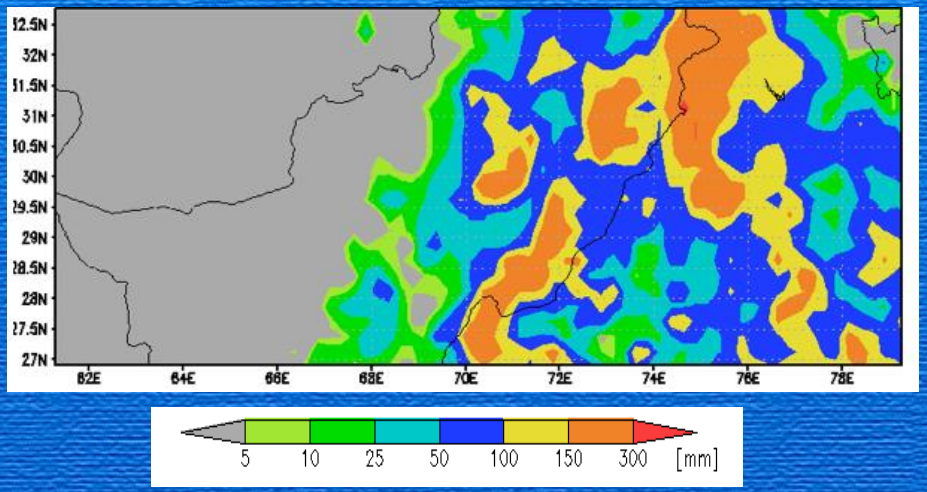
Example: Detection of Recent Flooding in Pakistan

20 August 2013
06 GMT

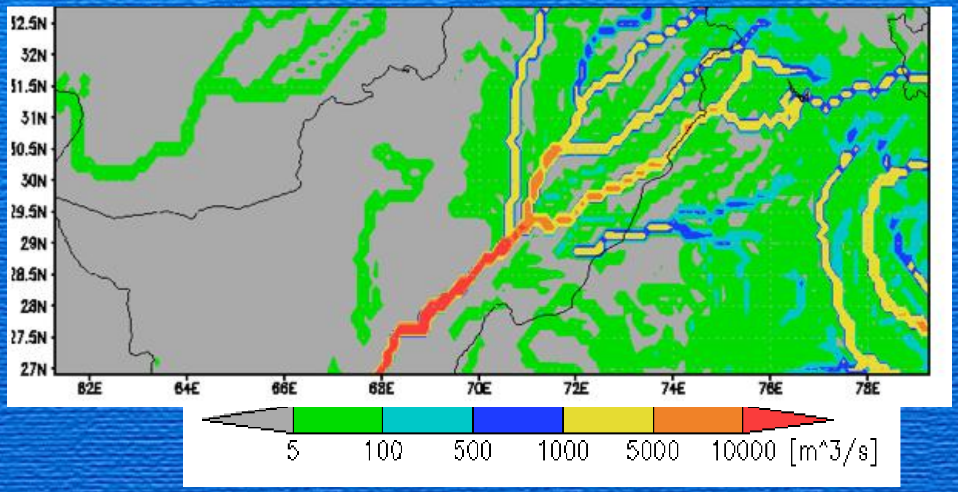
Flood Detection/Intensity (Depth above Threshold [mm])



Rainfall (7 day Accumulation [mm])



Streamflow [m³/s]

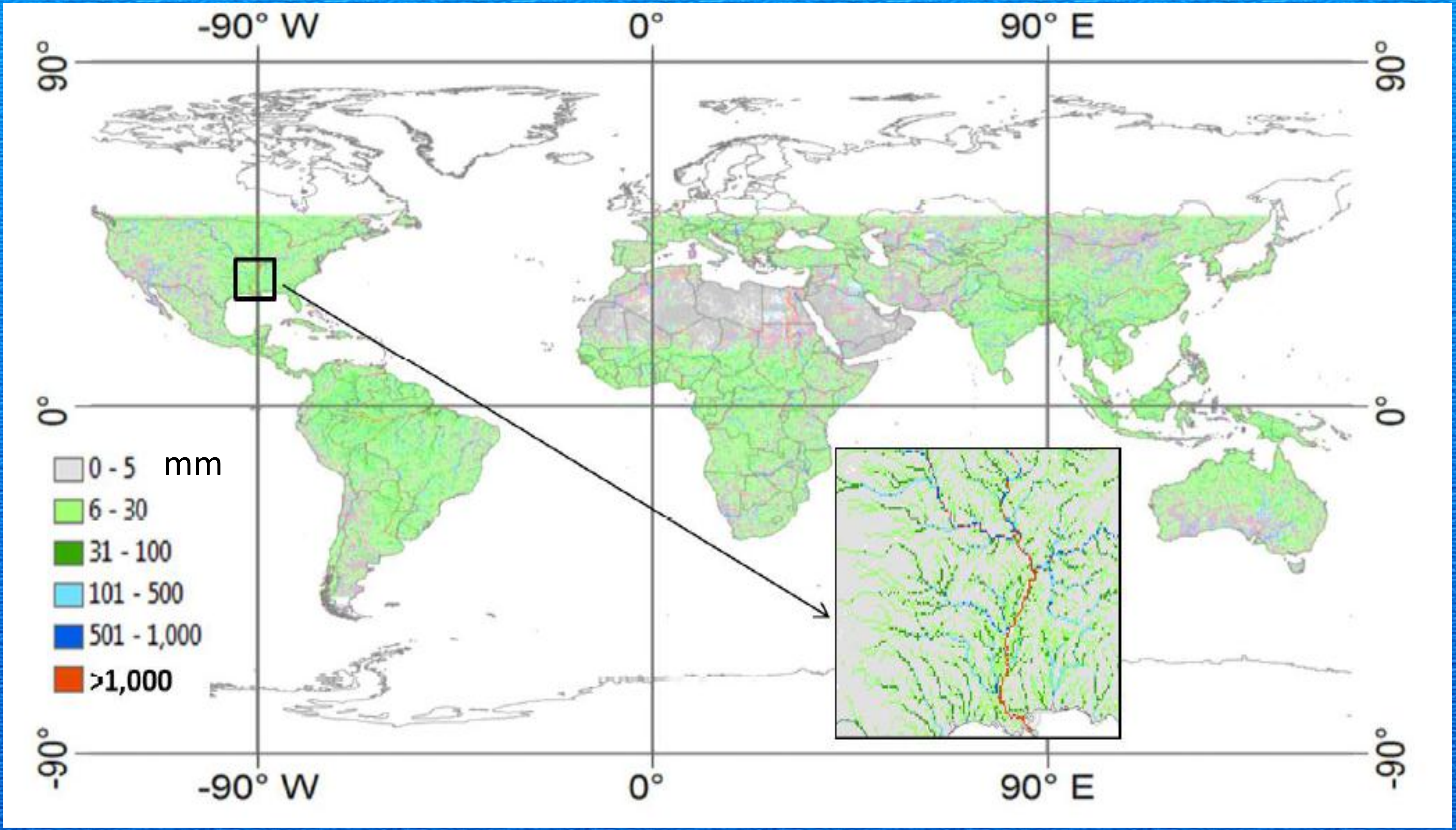


http://flood.umd.edu

Routed runoff [mm] based Flood Threshold Map

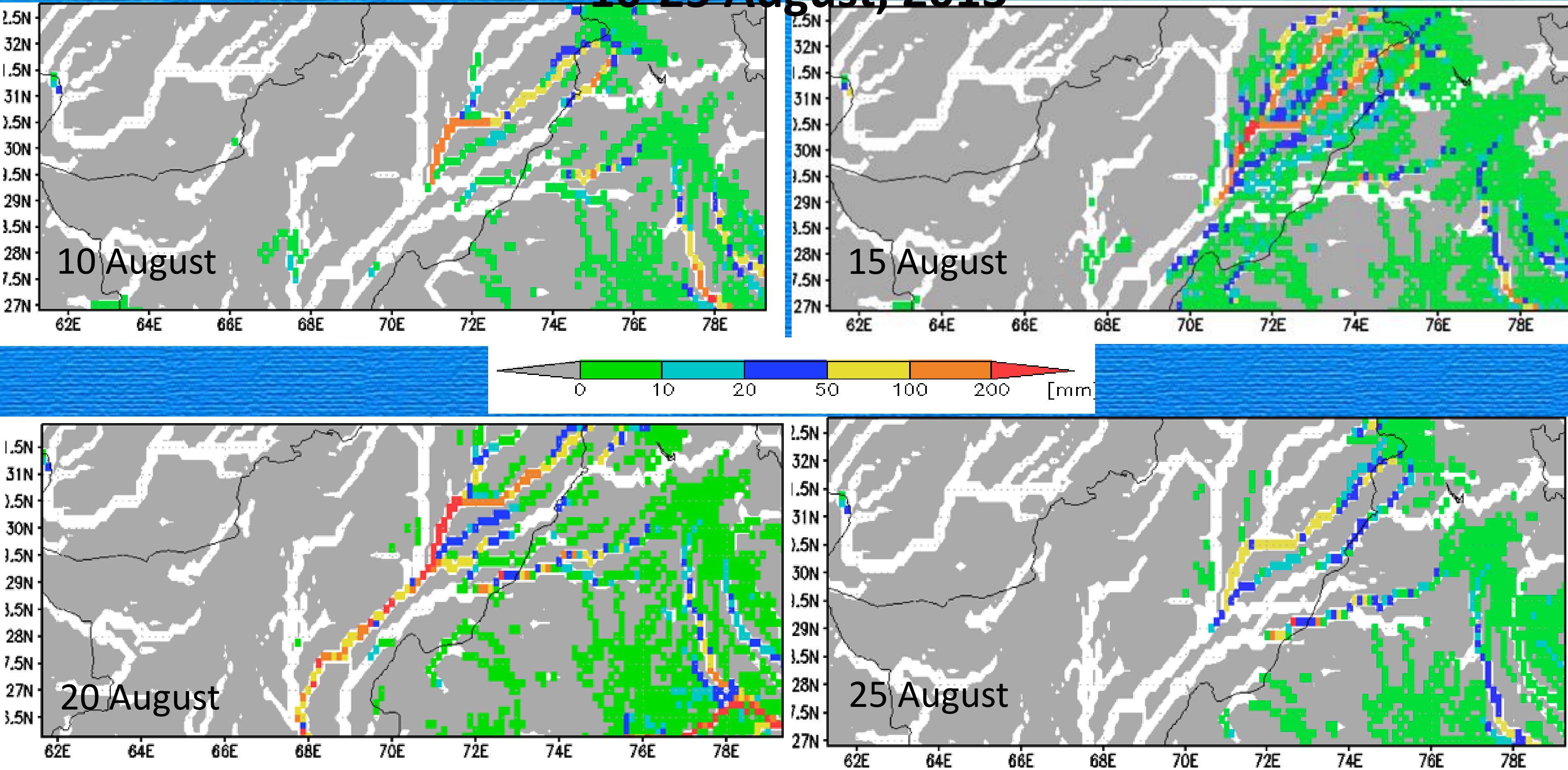
Threshold=P_{95} + δ

P_{95}: 95th percentile value of routed runoff
δ: temporal standard deviation of routed runoff



15-year global hydrology model run using satellite rainfall data.

Flood Detection/Intensity (depth above threshold [mm])
10-25 August, 2013



$$R > P_{95} + \delta$$

and

$$Q > 10\ m^3/s$$

R: ***routed runoff (mm)***

P_{95}: ***95^{th} percentile value of routed runoff***

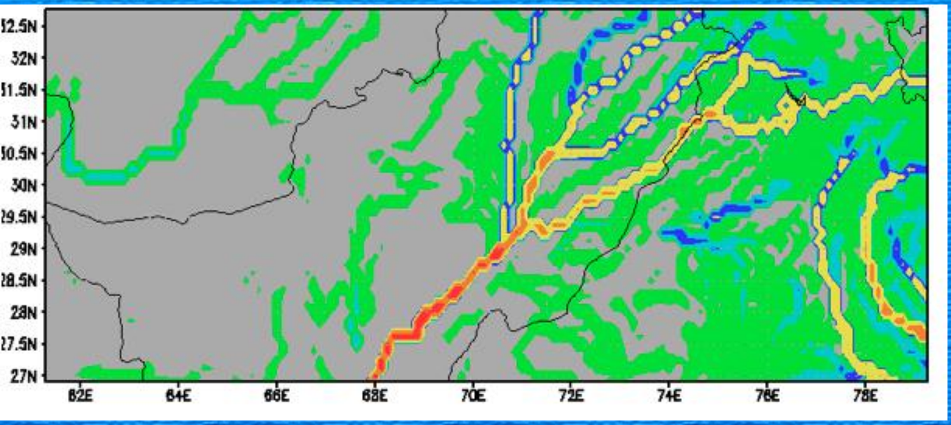
δ: ***temporal standard deviation of routed runoff***

Q: ***discharge (m^3/s)***

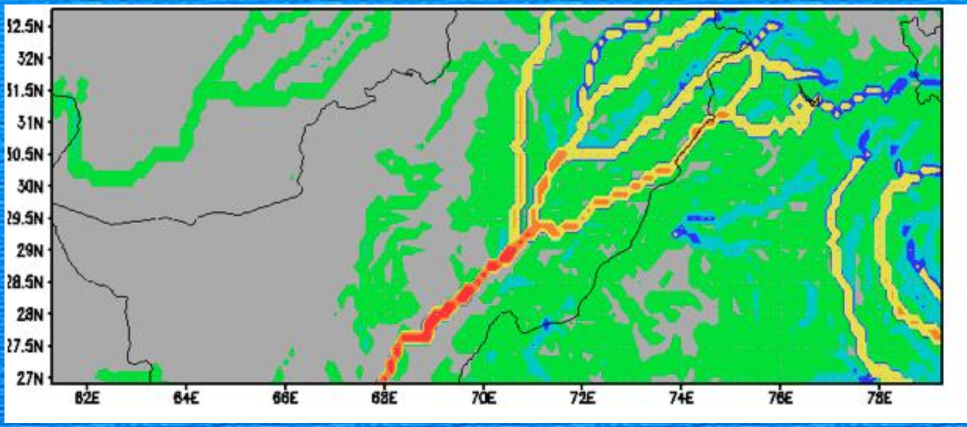
Streamflow [m^3/s]

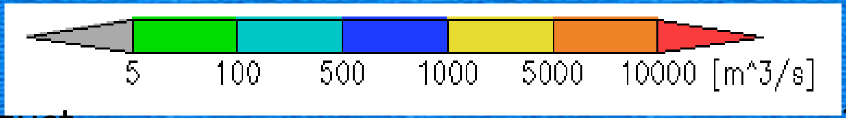
August 10-25, 2013

10 August

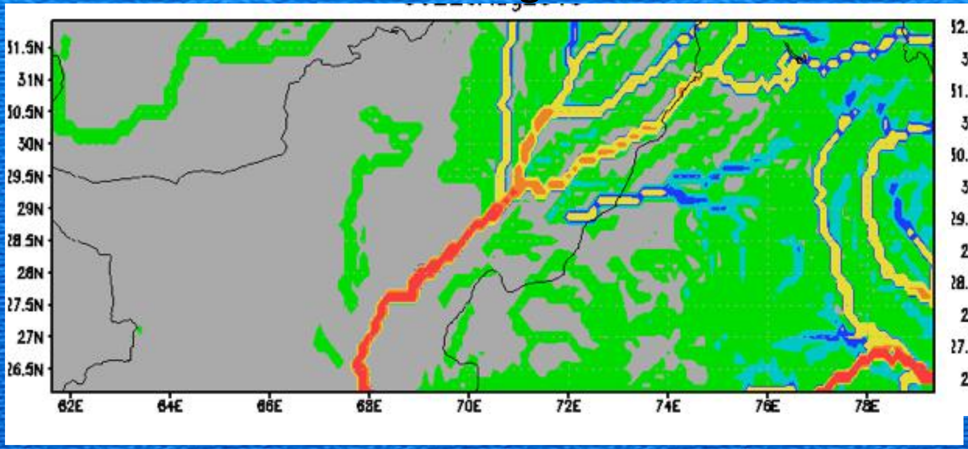


15 August

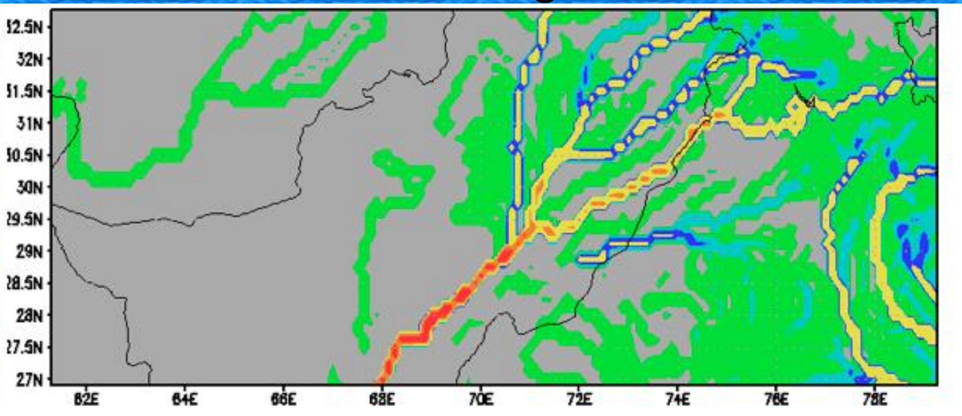




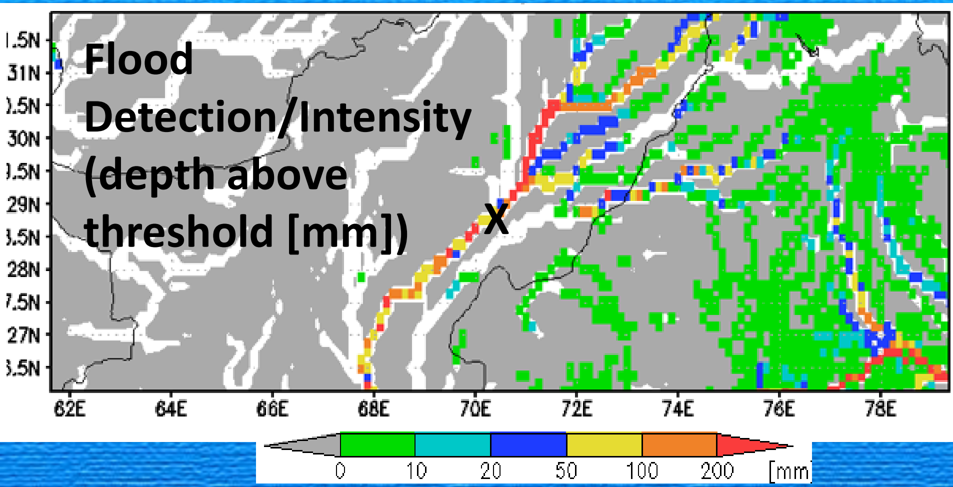
20 August

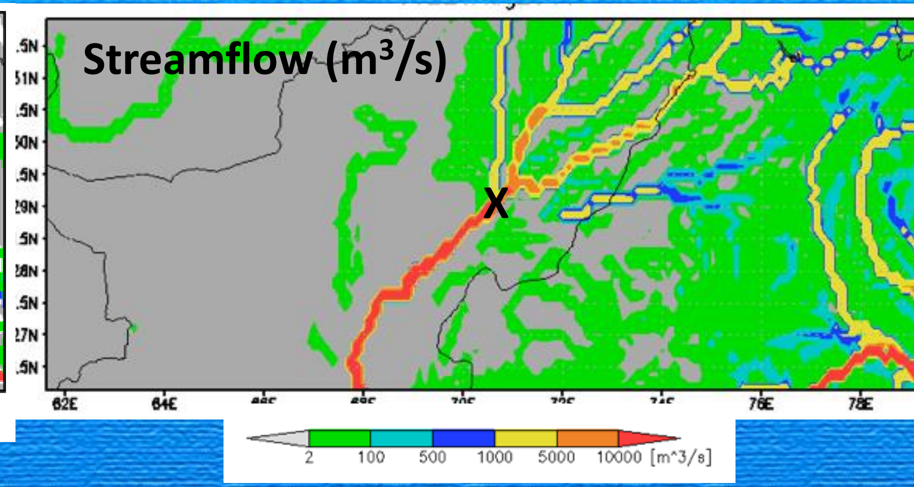


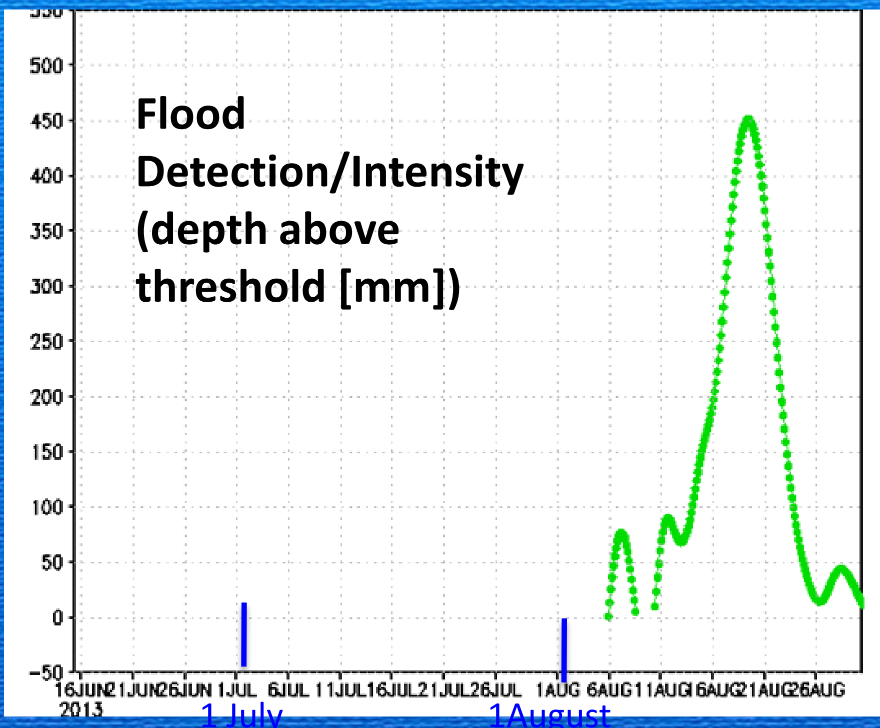
25 August

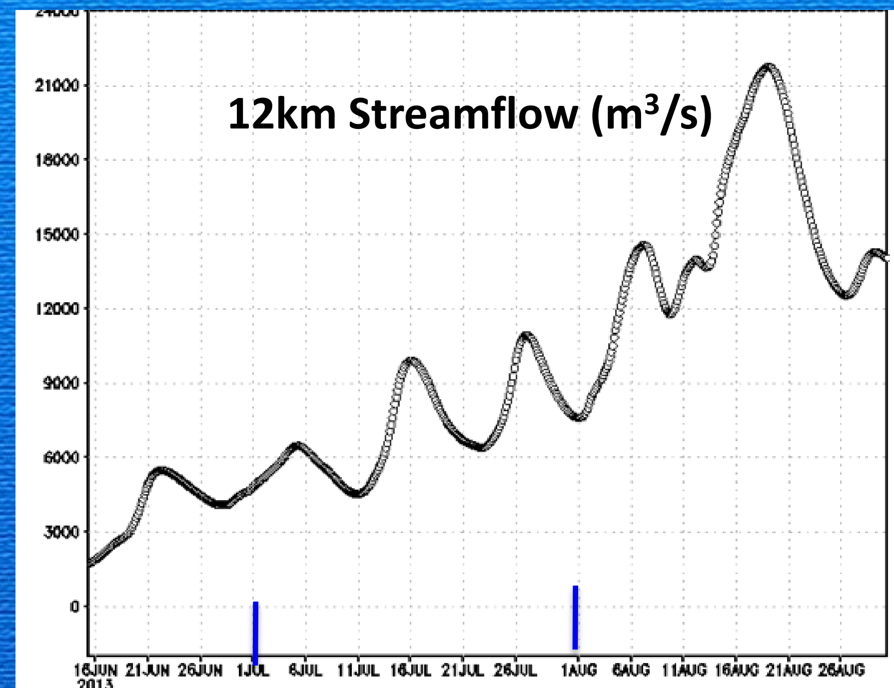


Recent Flooding in Indus River, Pakistan (20 august 2013)





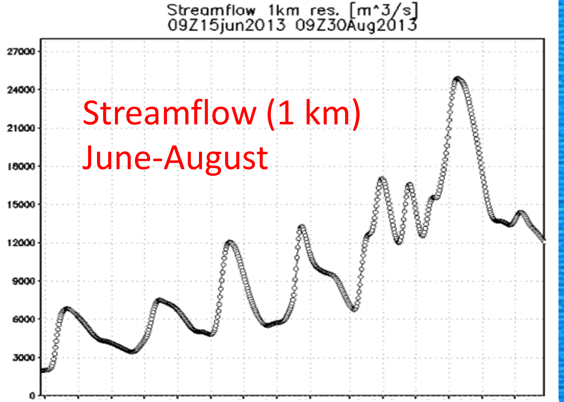


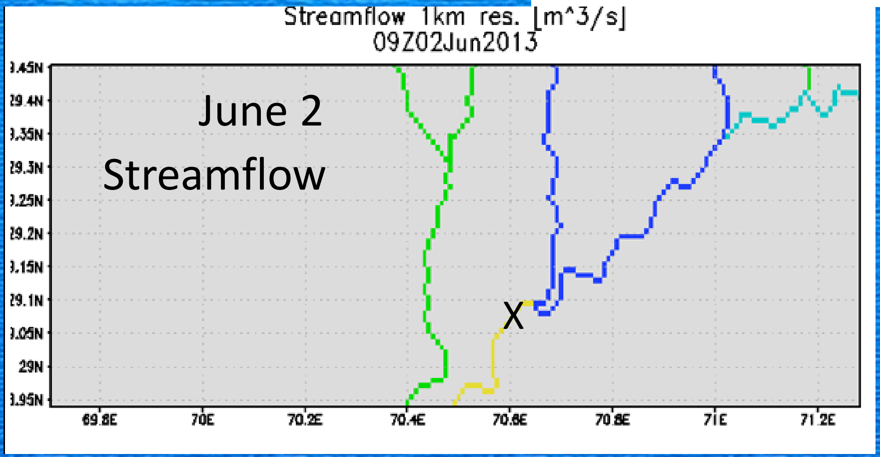


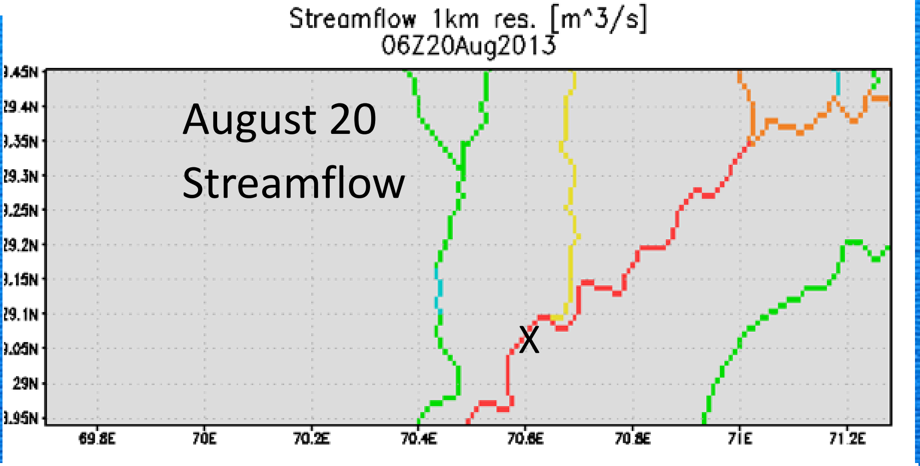
1 July 1August

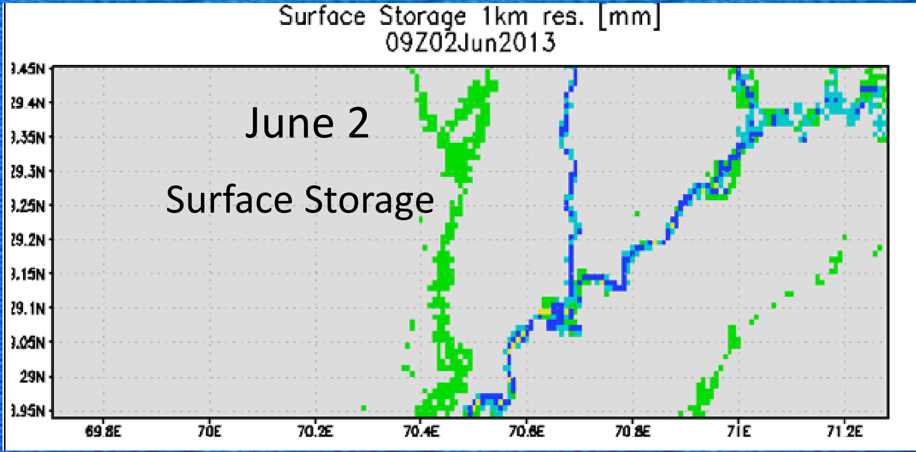
Real-time Calculations at 1 km

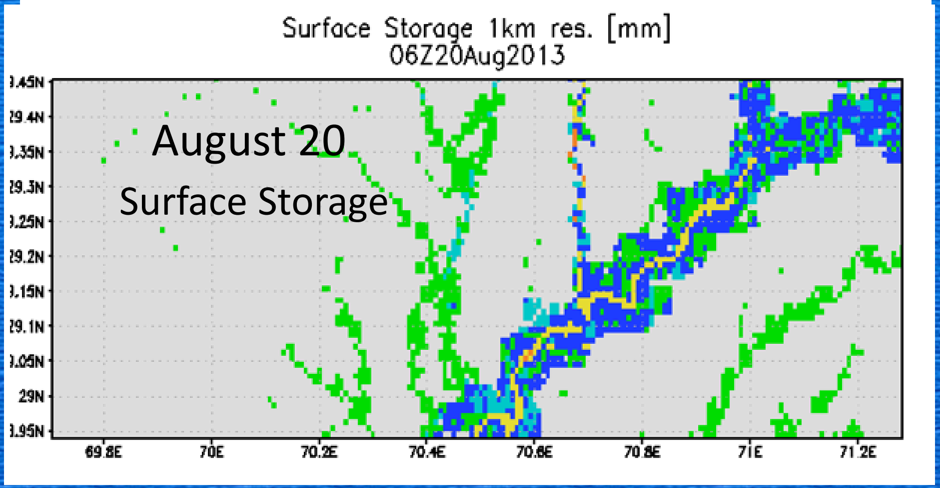
Streamflow and
Water Storage (Routed Runoff + Bank Overflow)











Global evaluation TMPA real-time (DRIVE-RT) and research (rain gauge adjusted, DRIVE-V7) [15yrs (1998~), 3-hrly, 12km res.]

(1) **Flood event** based evaluation using 2,086 archived flood events by Dartmouth Flood Observatory

(2) **Streamflow** based evaluation at 1,221 river gauges by GRDC, across the globe.

Real-time Global Flood Estimation using Satellite-based Precipitation and a Coupled Land Surface and Routing Model (2013). Wu, Adler et al. Submitted to WRR
[manuscript available on http://flood.umd.edu/]

Flood event based evaluation

Flooding at a point

$R > P_{95} + \delta$

and

$Q > 10\ m^3/s$

R: *routed runoff (mm)*

P_{95}: *95th percentile value of routed runoff*

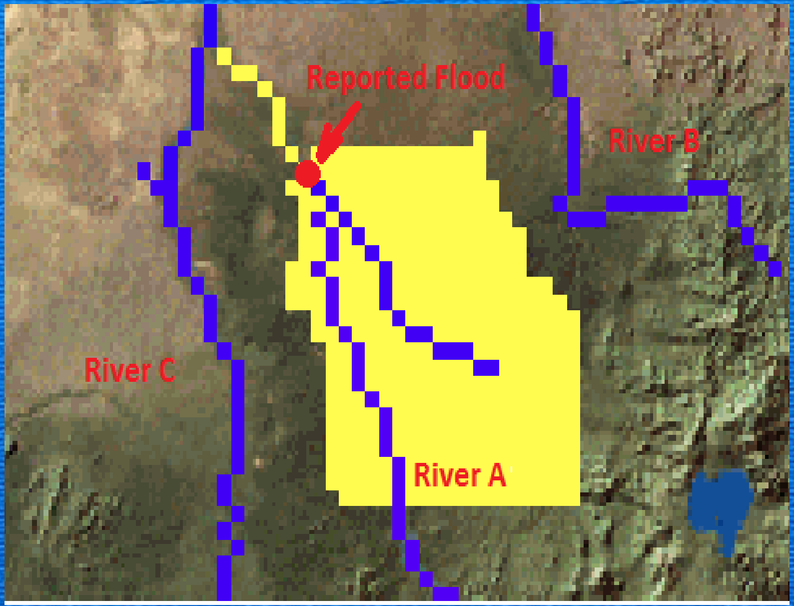
δ: *temporal standard deviation of routed runoff*

Q: *discharge (m^3/s)*

Matching floods between simulated and reported

Temporal window: ±1 days

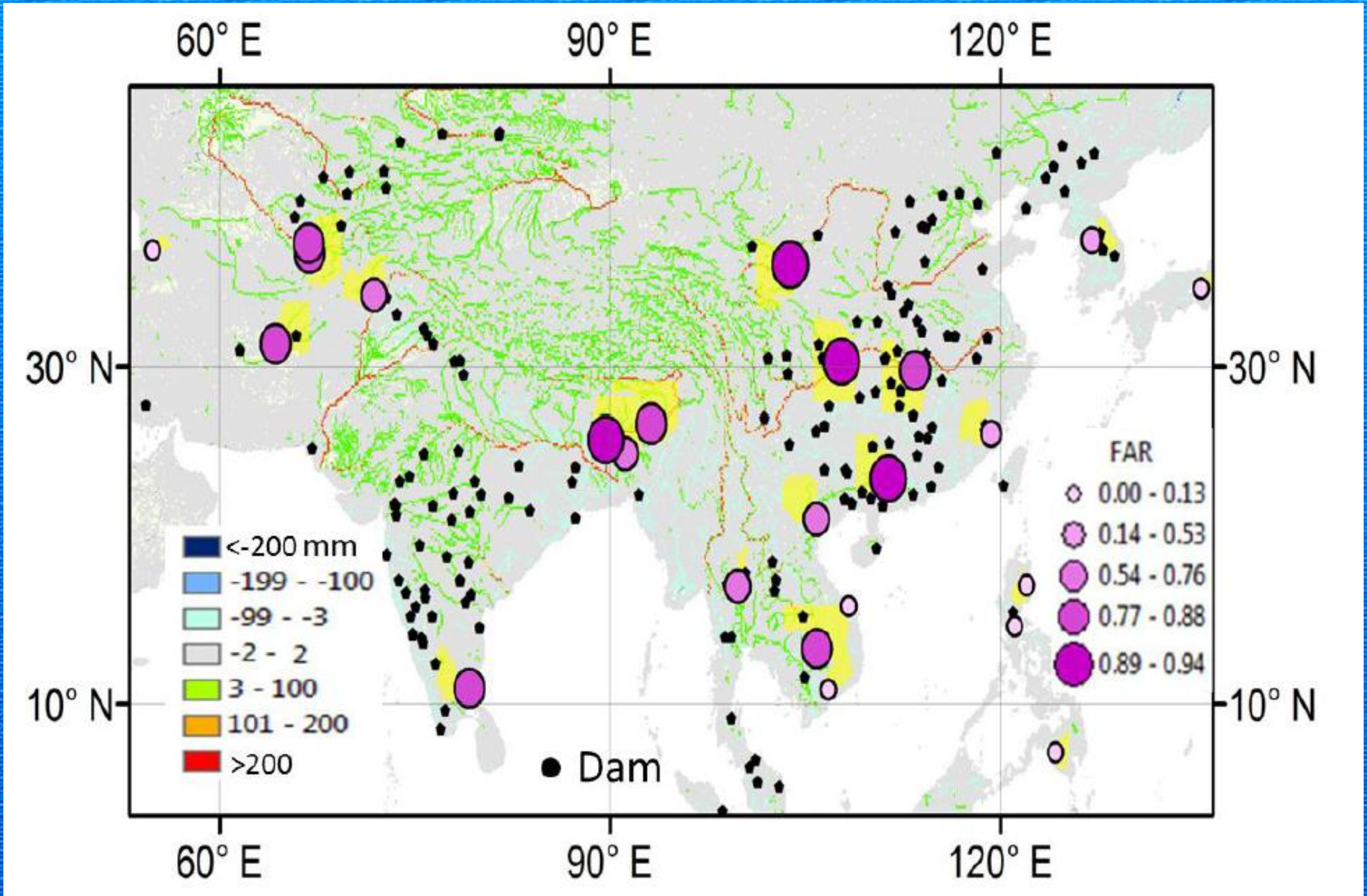
Spatial window: all upstream basin area within ~200 km & ~100 km downstream stem river



Wu H., R. F. Adler, Y. Hong, Y. Tian, and F. Policelli (2012), Evaluation of Global Flood Detection Using Satellite-Based Rainfall and a Hydrologic Model. J. Hydrometeor, 13, 1268.1284.

Validation Against Global Flood Events (Dartmouth Flood Observatory)

Example of Well Reported Areas [WRAs] (shaded in yellow) and their corresponding FAR metrics for all floods with duration greater than 1 day

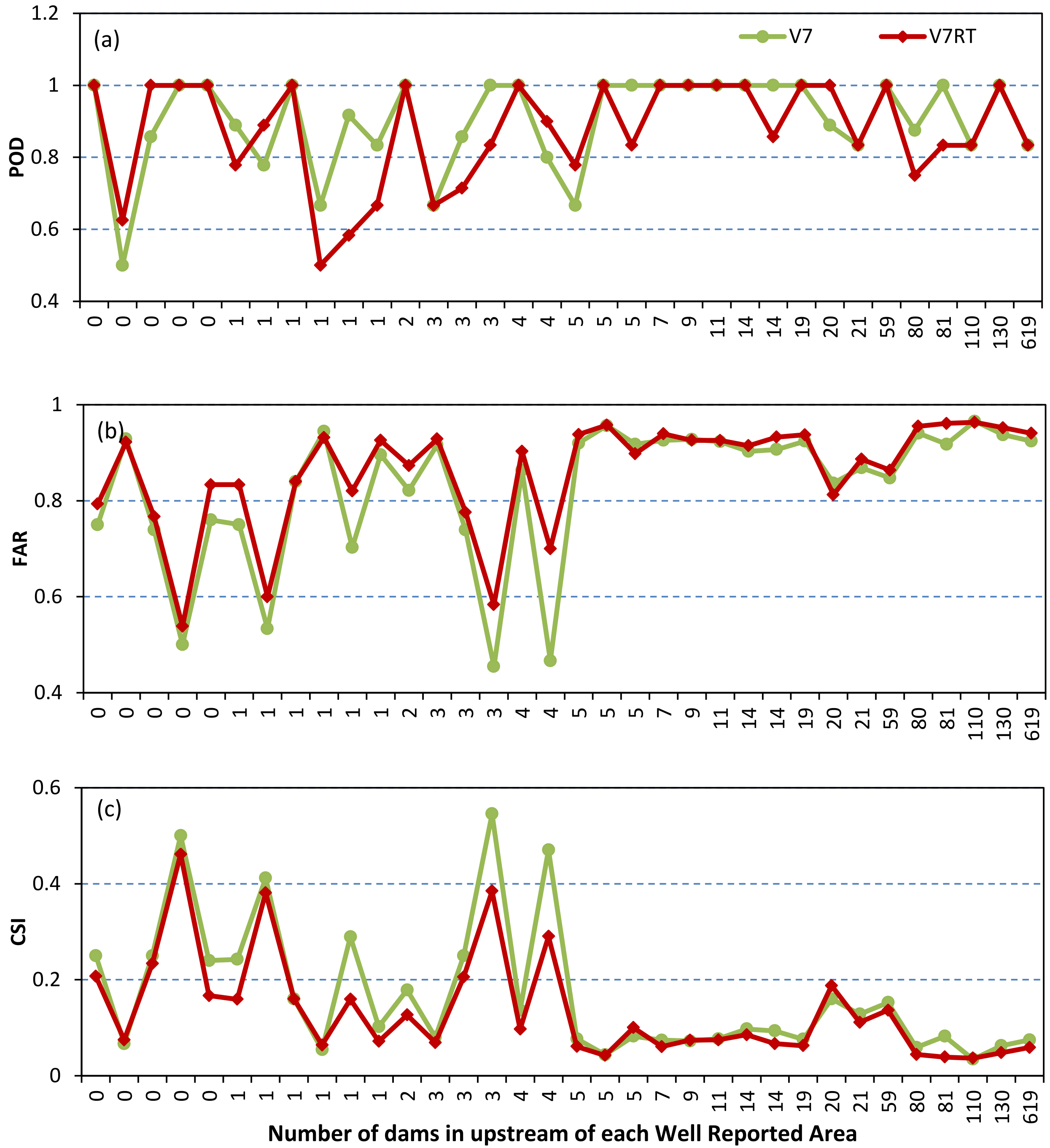


Flood detection verification against the Dartmouth Flood Observatory (DFO) flood database over the 38 Well Reported Areas (WRAs) for floods with duration more than 3 days.

Metrics	POD	FAR	CSI
Metrics averaged over all the 38 WRAs			
DRIVE-V7RT	0.90	0.73	0.25
DRIVE-V7	0.93	0.65	0.34
Metrics averaged over the 20 WRAs with ≥ 5 dam			
DRIVE-V7RT	0.93	0.80	0.19
DRIVE-V7	0.94	0.73	0.26
Metrics averaged over the 18 WRAs with < 5 dam			
DRIVE-V7RT	0.87	0.66	0.32
DRIVE-V7	0.92	0.56	0.43

Better flood detection statistics with "research" (instead of RT) rain, with fewer dams (drop in FAR) and for longer, larger floods

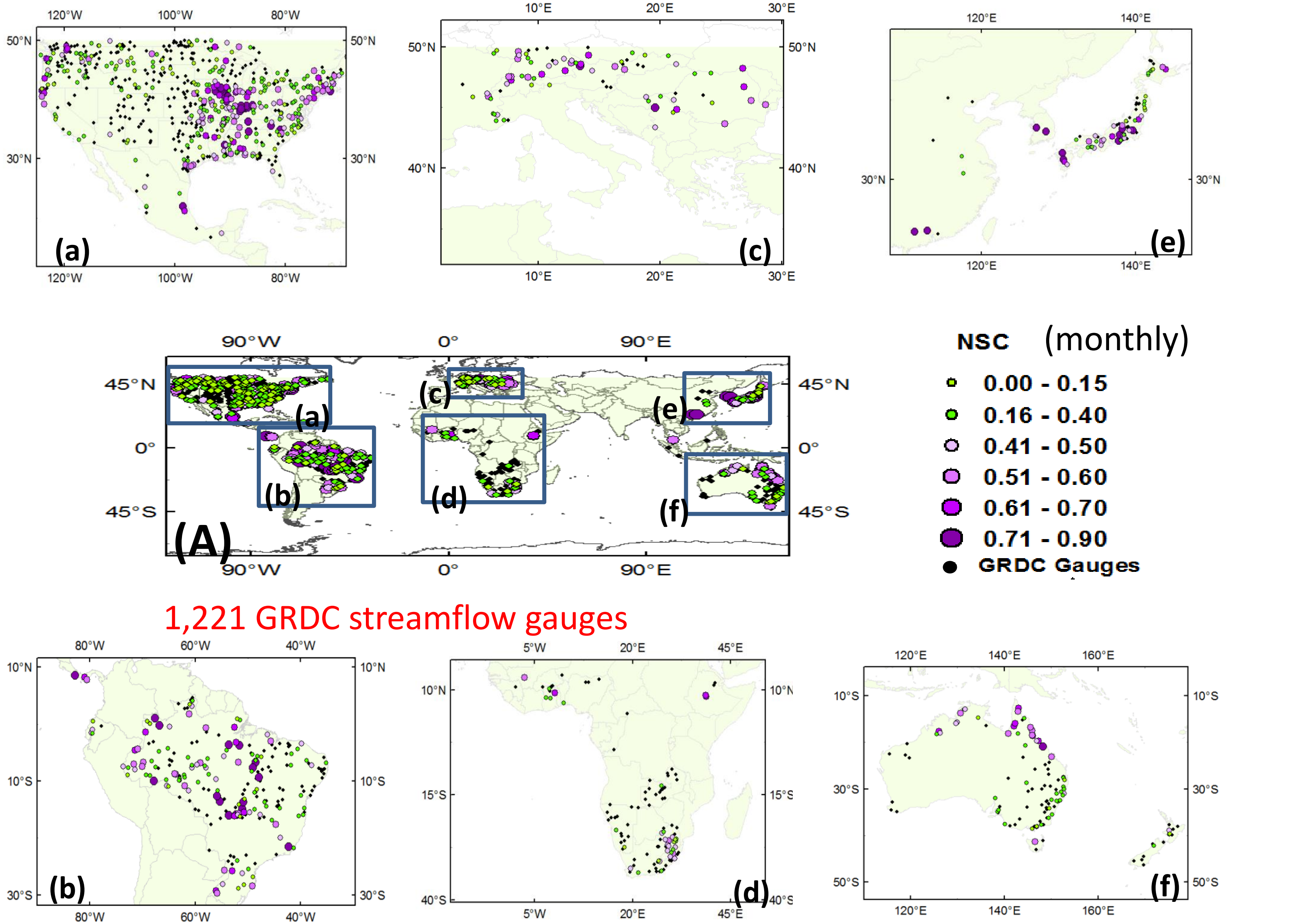
Bottom line--For 3-day floods in basins with few dams using RT rainfall: POD ~ 0.9 FAR ~ 0.7



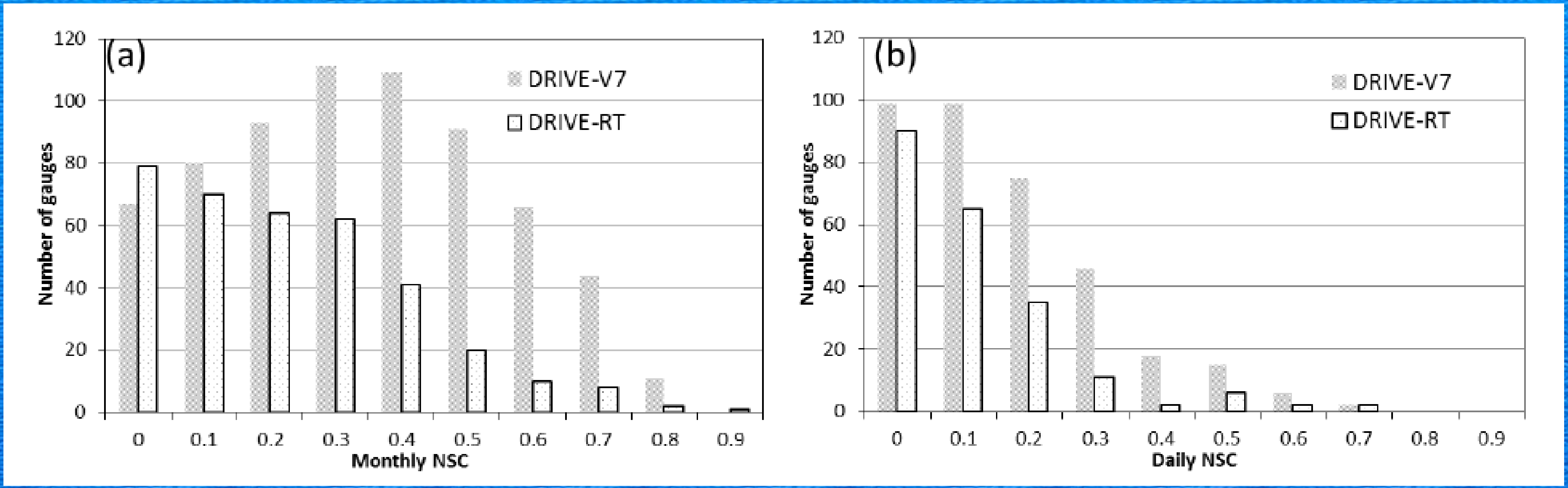
(a)
V7
V7RT
POD
(b)
FAR
(c)
CSI
0 0 0 0 0 1 1 1 1 1 1 2 3 3 3 4 4 5 5 5 7 9 11 14 14 19 20 21 59 80 81 110 130 619
Number of dams in upstream of each Well Reported Area

River gauges based evaluation

DRIVE-V7 (12km res.)



Distribution of the number of gauges with positive monthly and daily NSC metrics for DRIVE-V7 and DRIVE-RT simulation for 2001-2011, respectively



Better NSC statistics for "research" rainfall indicate potential improvement of streamflow estimations when satellite rainfall improves

Comparison with GRDC Streamflow Gauges

Nash-Sutcliffe (NSC) Daily and Monthly

Mean annual Relative Error (MARE)

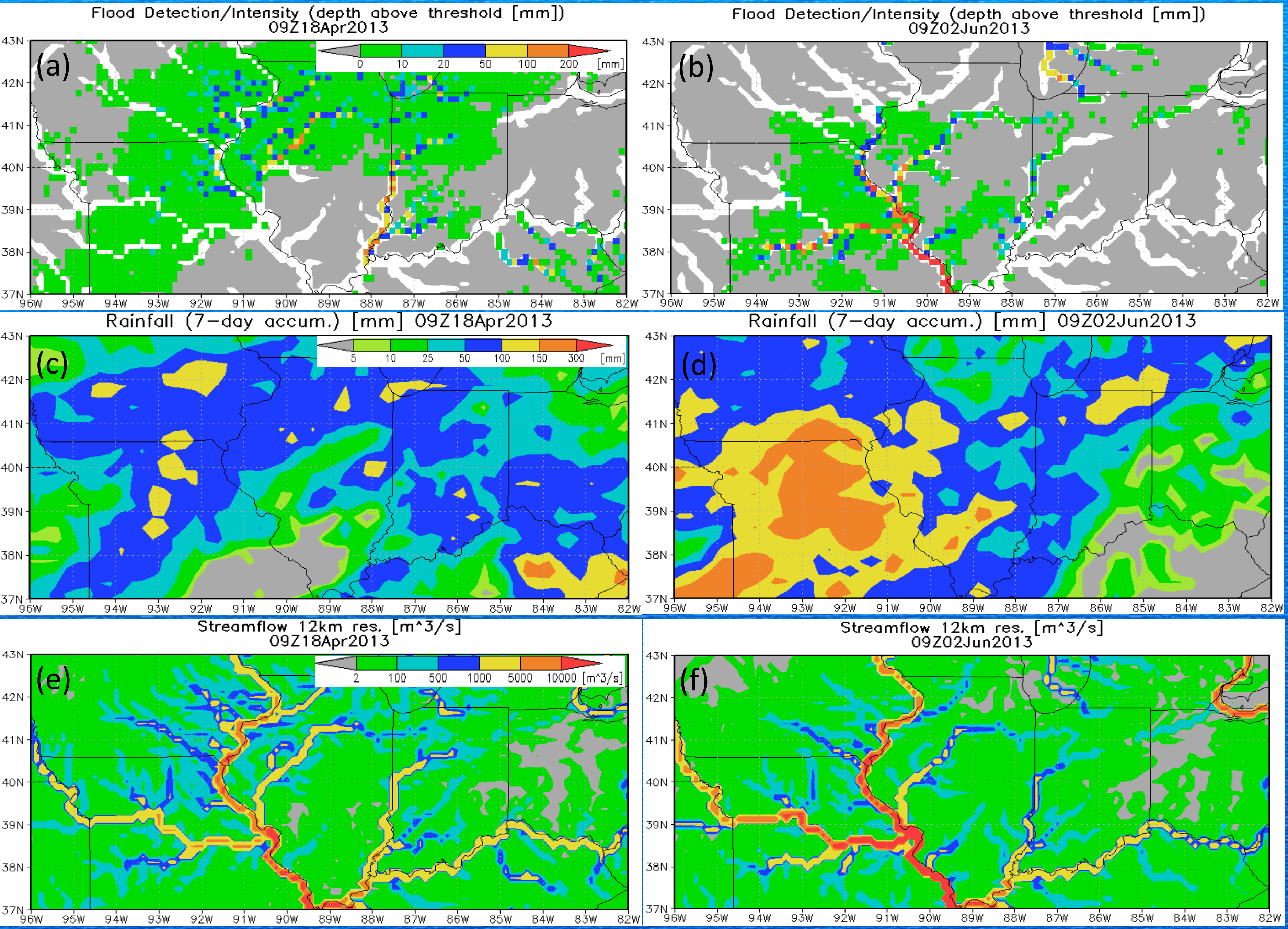
		Daily NSC		Monthly NSC		Correlation Coeff.		MARE<30%
		$N_d>0$	$N_d>0.4$	$N_m>0$	$N_m>0.4$	$R_d>0.4$	$R_m>0.4$	
Global (-50°S to 50°N) with 1,121 gauges								
% of gauges	V7	32	4	60	29	58	99	38
	V7RT	*19*	*1*	*32*	*7*	*42*	*95*	*27*
Mean metrics	V7	0.22	0.52	0.39	0.57	0.57	0.67	-0.3%
	V7RT	*0.16*	*0.57*	*0.27*	*0.54*	*0.53*	*0.53*	*-2.9%*
-10°S~10°N with 141 gauges								
% of gauges	V7	44	9	62	31	76	99	44
	V7RT	*39*	*6*	*57*	*22*	*75*	*98*	*51*
Mean metrics	V7	0.25	0.55	0.41	0.58	0.64	0.70	-6.8%
	V7RT	*0.23*	*0.60*	*0.36*	*0.58*	*0.61*	*0.66*	*-5.5%*

Results are positive, but show considerable room for improvement

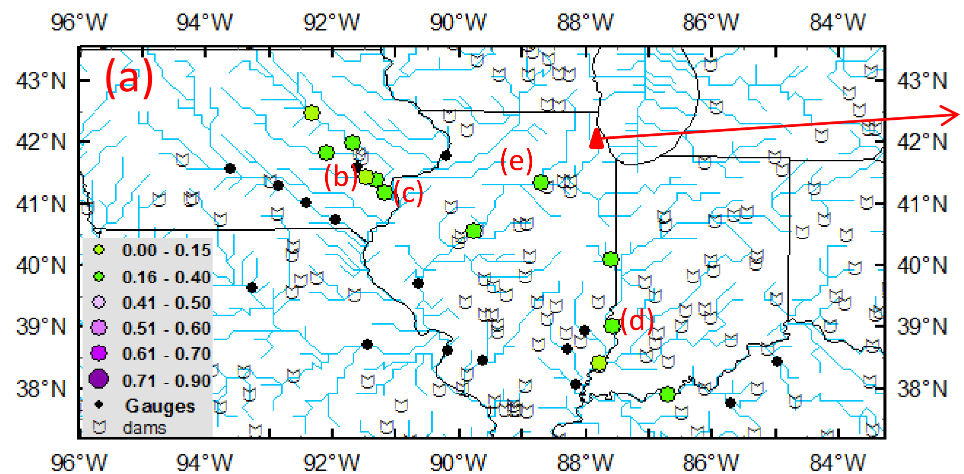
Tropics show better results than global, indicating problems in cool season, higher latitudes; research precipitation shows generally better results over real-time.

Tropics show lower bias with RT, indicating research procedure to reduce rain bias with rain gauges not working well in tropics where rain gauges are sparse

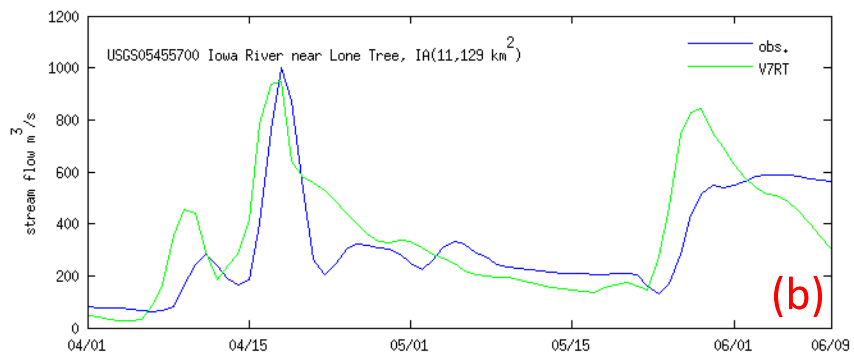
Evaluation of on-line events

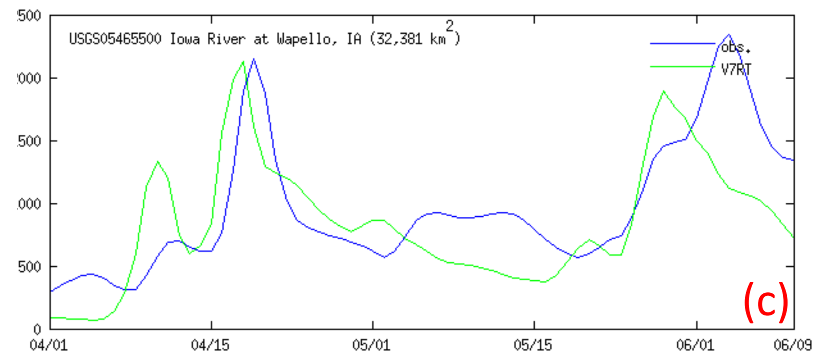


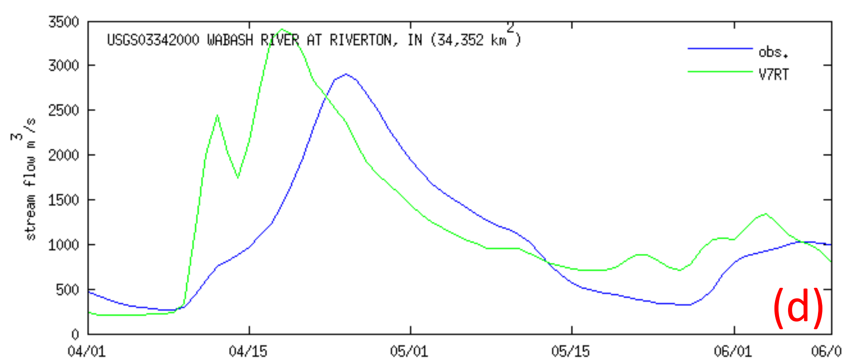
Evaluation of on-line events

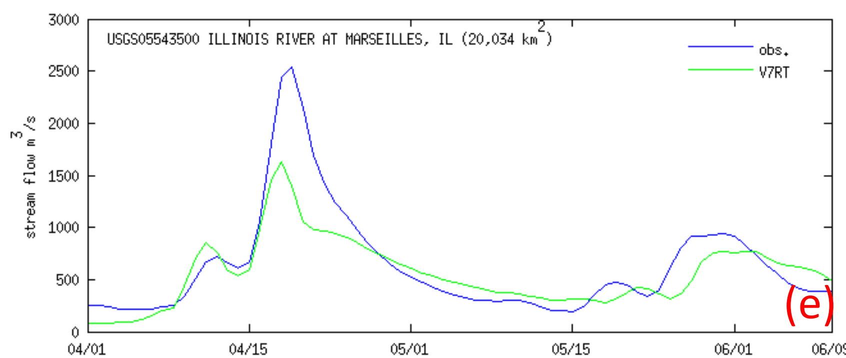


Internet source: April 19, 2013, Des Plaines, IL

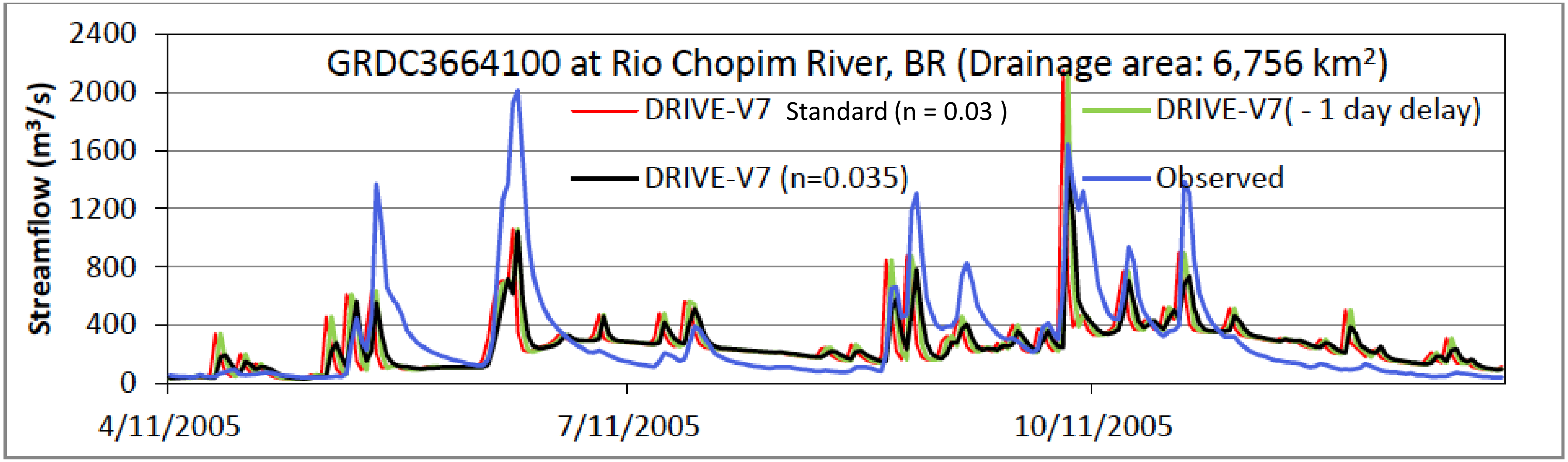








Flood Wave Too Fast?

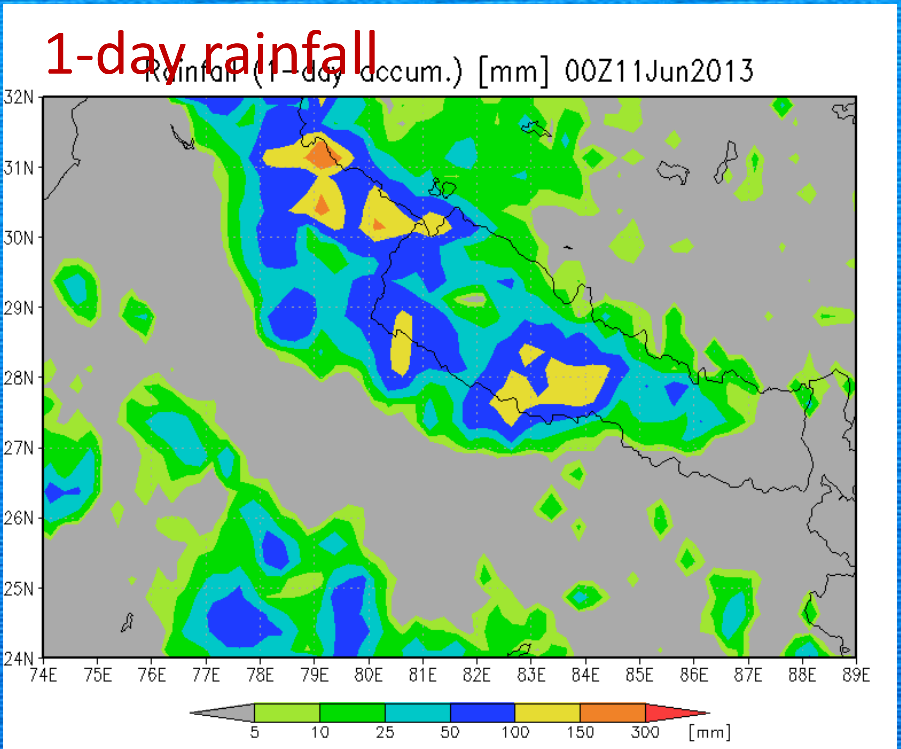


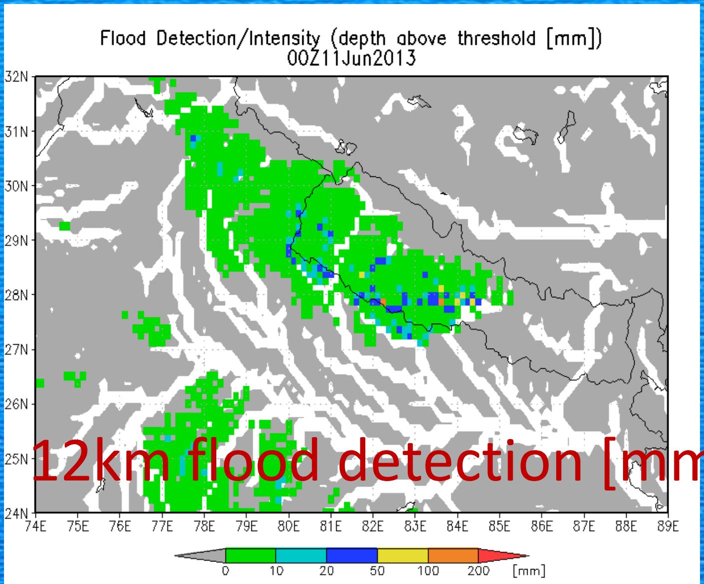
Experiment 1: Example hydrograph with 1 day lag gives better results. Larger rivers may have larger lag.

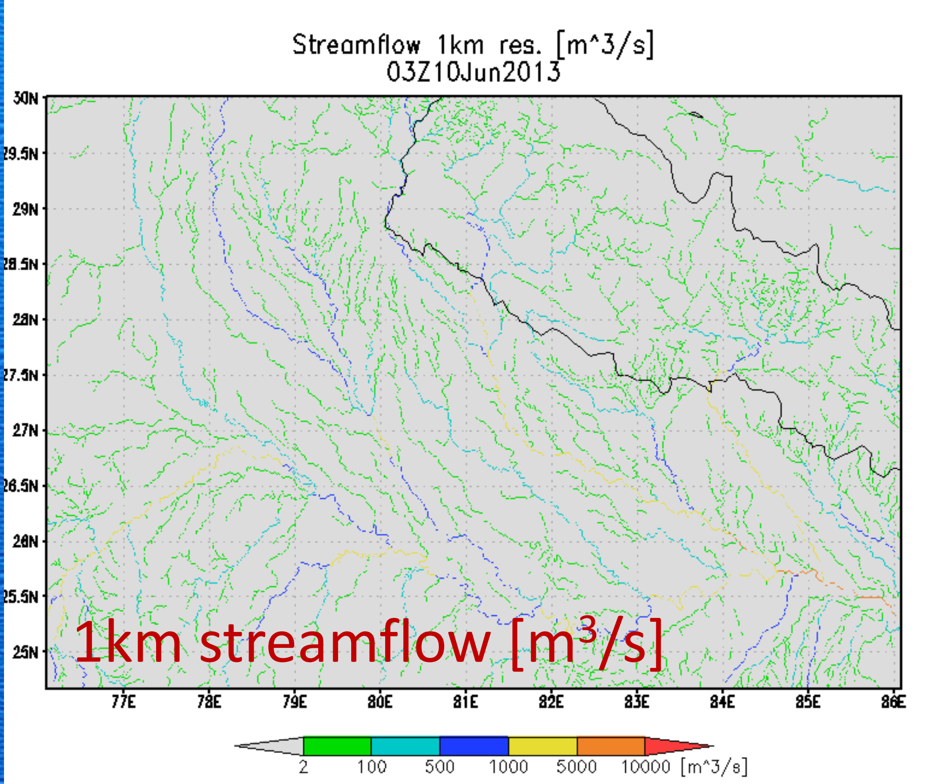
Experiment 2: Increase of Manning parameter (streambed roughness) to .035 (from .03) also provides better timing—in this one case.

Further model tuning and calibration will likely improve results.

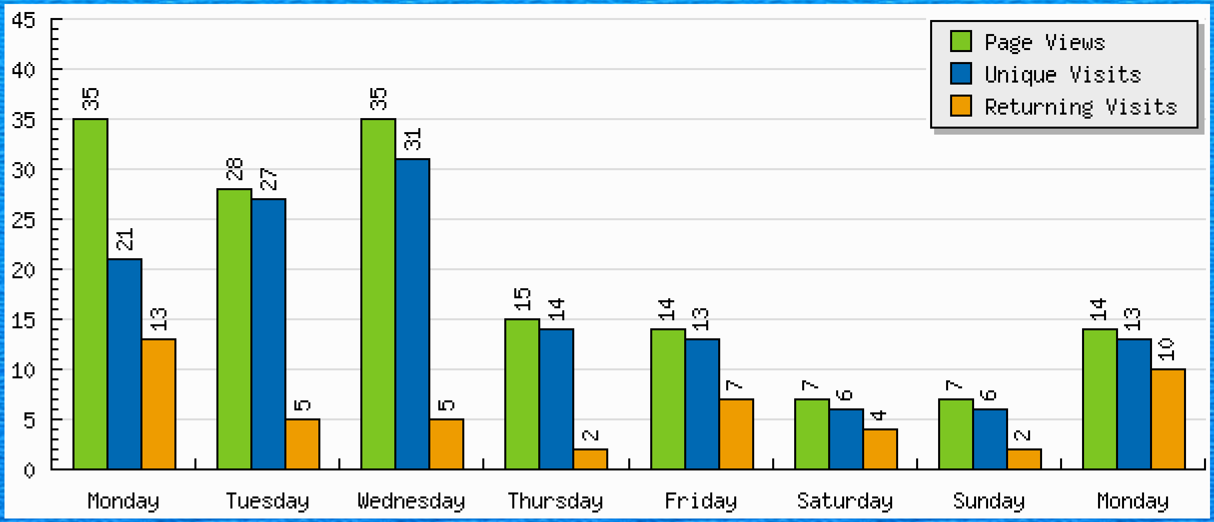
http://flood.umd.edu/temp/share.html







"The last 10-day flood evolution, rainfall, and streamflow simulations (at 1km resolution)
for north India (north sub-basins of Ganges)
The flood during last week has been reported killing more than 130 people in this area."



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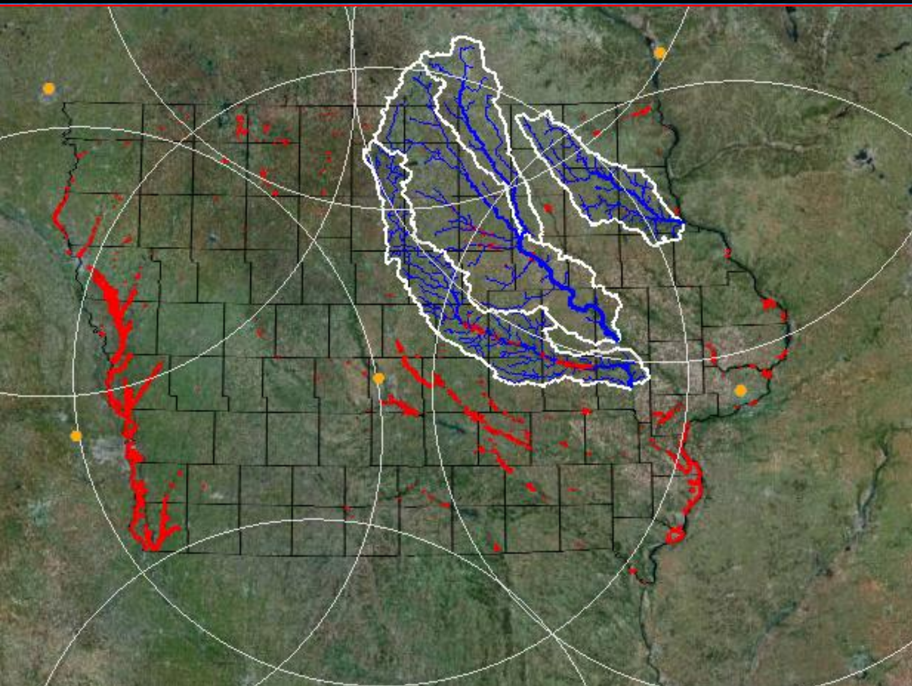
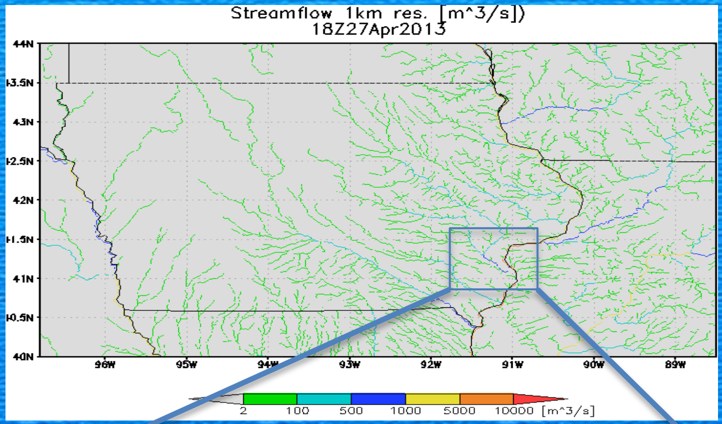
Colombia
DR Congo
Brazil
Peru
Bolivia
Angola
Namibia
Botswana
Madagascar
South Africa
Indian Ocean
South Atlantic Ocean
South Pacific Ocean
Argentina
Indonesia
Papua New Guinea
New Zealand

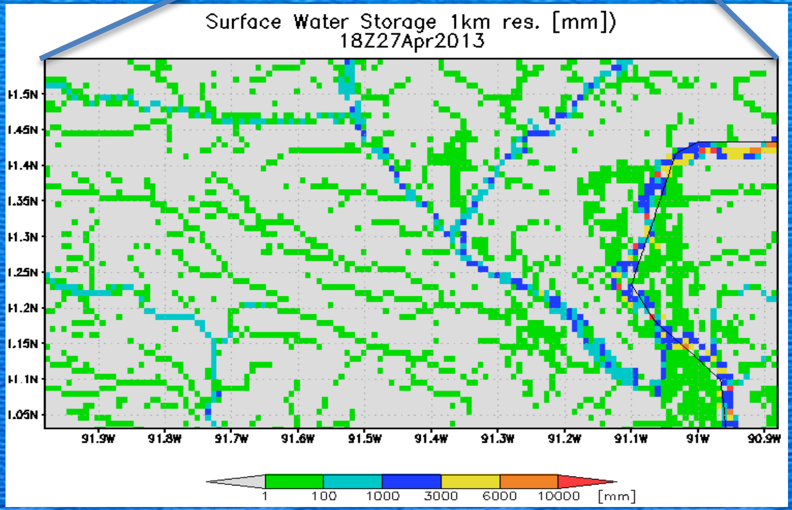
IFloodS Iowa Flood Studies

http://flood.umd.edu/IFloods.html

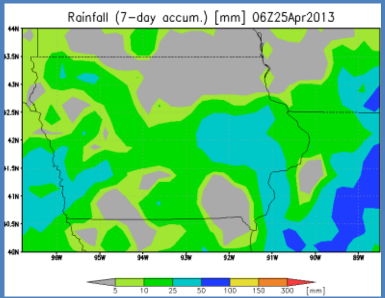


https://fcportal.nsstc.nasa.gov/ifloods/

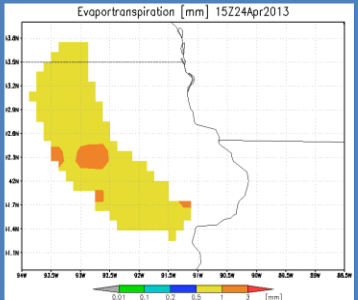




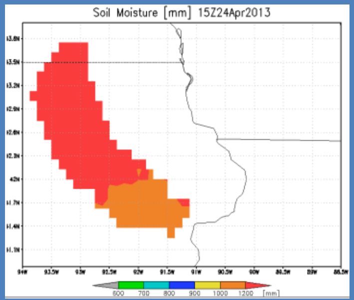
Precipitation



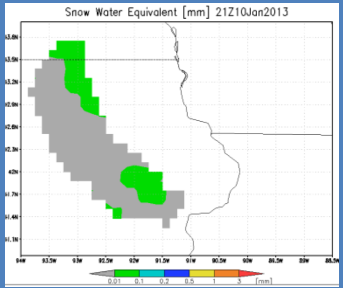
Evaportranspiration



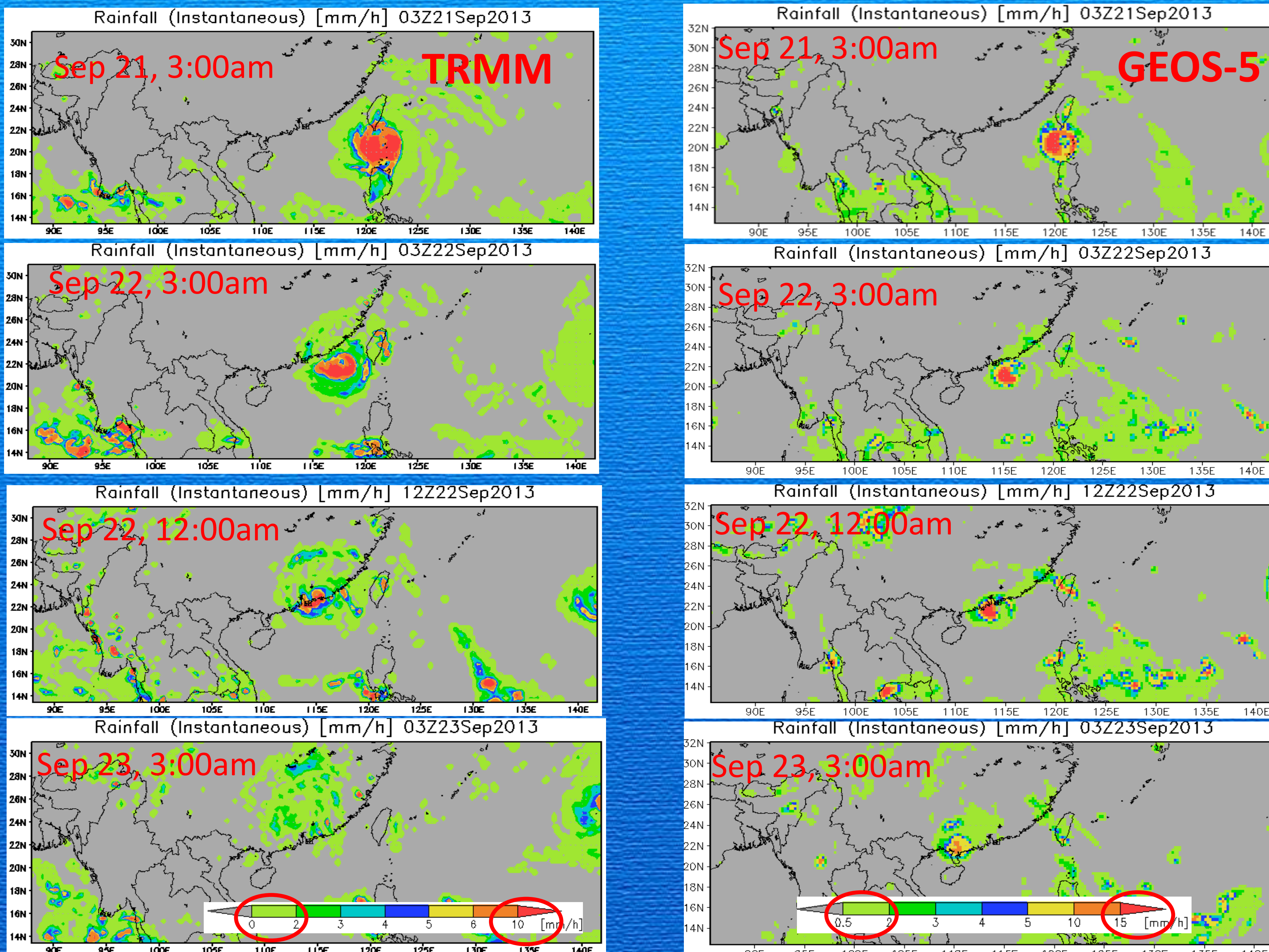
Soil moisture



SWE



~5-day lead Flood Forecasting



Summary and Future

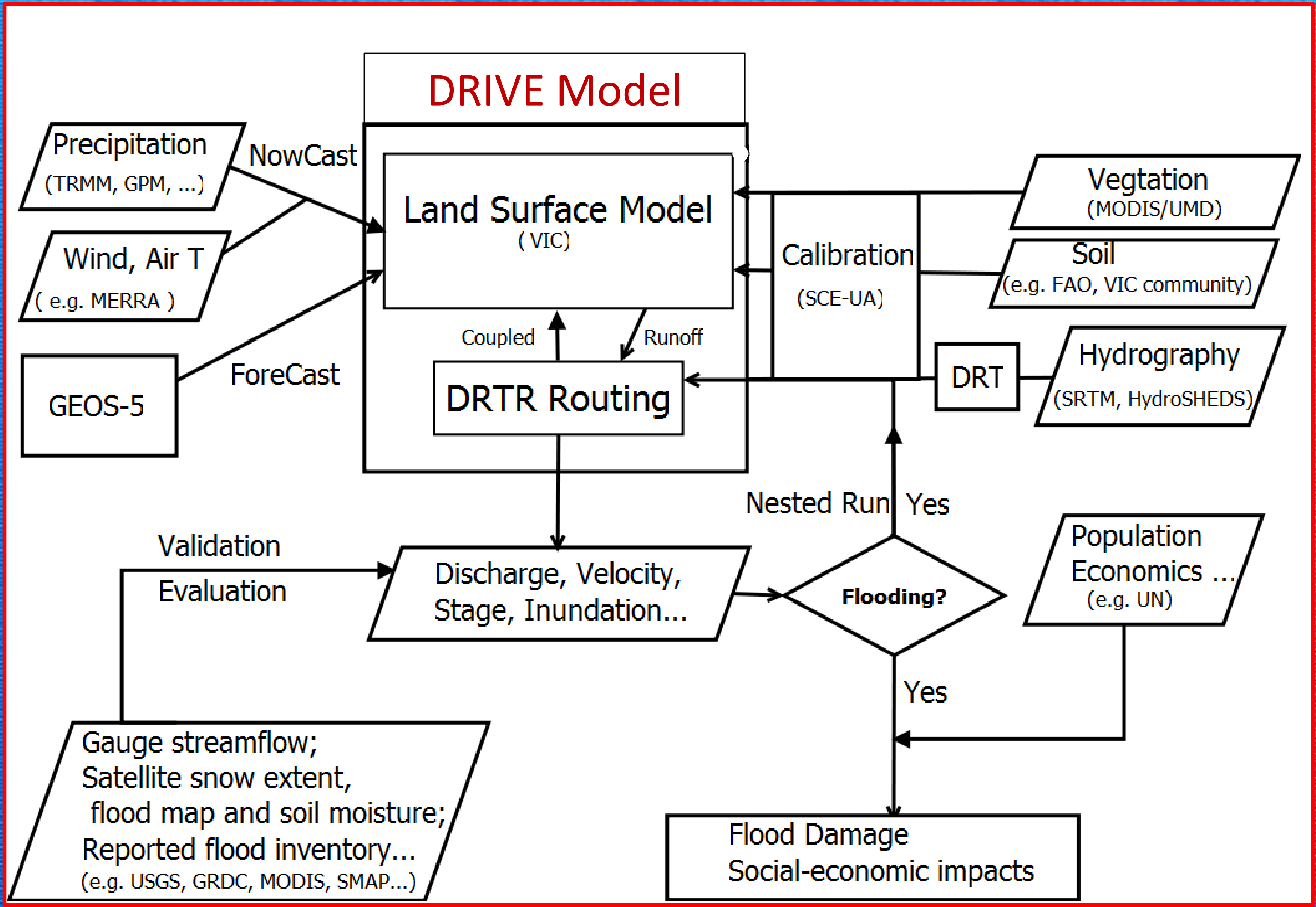
1. A new version of the Global Flood Monitoring System (GFMS) has been implemented for real-time application using the U. of Washington VIC community Land Surface Model and a new physically based DRTR routing model from the U. of Maryland for more accurate flood calculation and greater flexibility, including 1 km routing. The VIC/DRTR combination is called the Dominant river Routing Integrated with VIC Environment (DRIVE) system.

2. The evaluation of the DRIVE model shows promising performance in retrospective runs vs. observed streamflow records and in flood event detection against global flood event statistics. Results show impact of dams (higher FAR), potential improvement with improved accuracy of satellite precipitation and greater skill with longer floods.

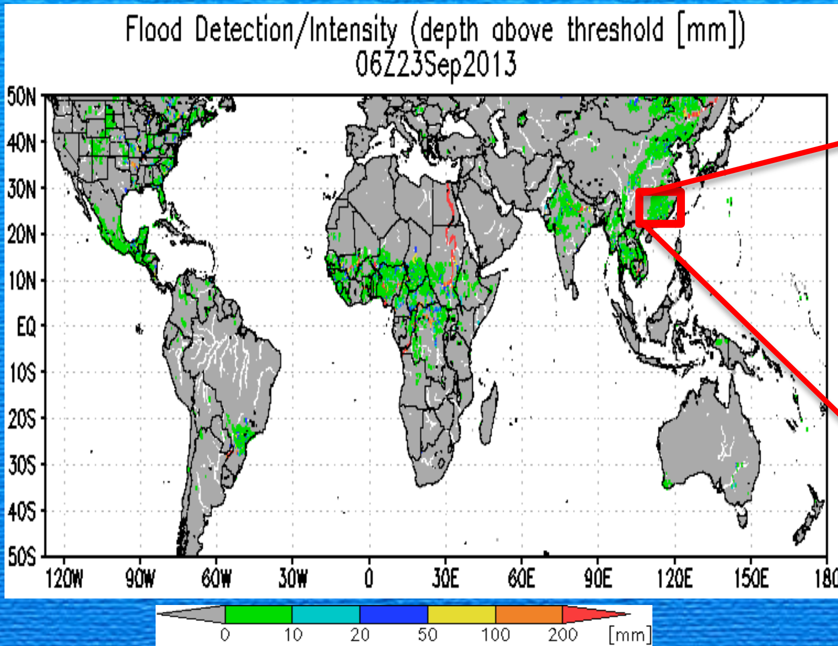
3. High resolution (1 km) routing and water storage calculations will lead to high resolution inundation mapping for comparison with high resolution visible and SAR imagery of floods.

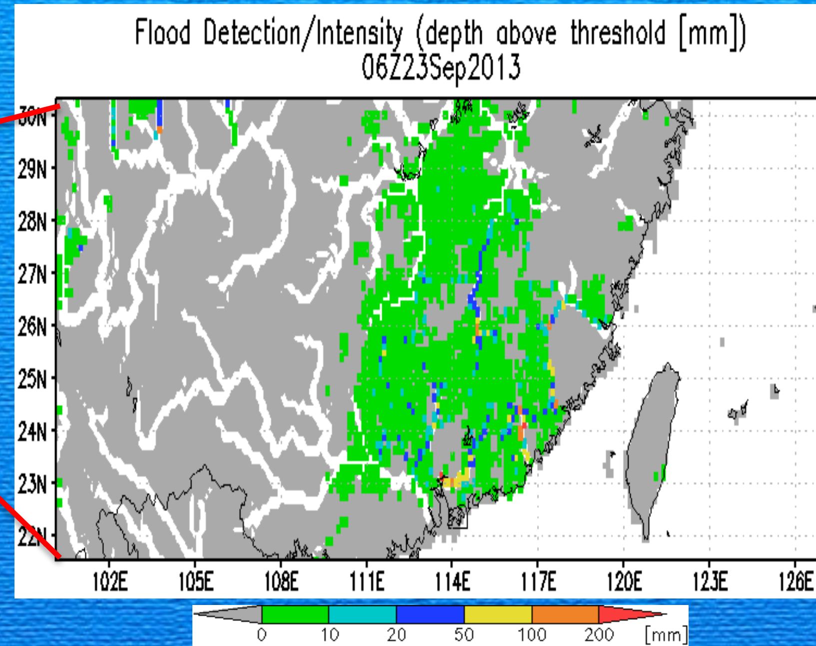
4. For the future we will also:
   - be implementing a “dam module” to try to include the impact of man-made structures on the calculations
   - be implementing the use of forecast precipitation info. from numerical models (adjusted by the satellite estimates) to extend the calculations a few days into the future

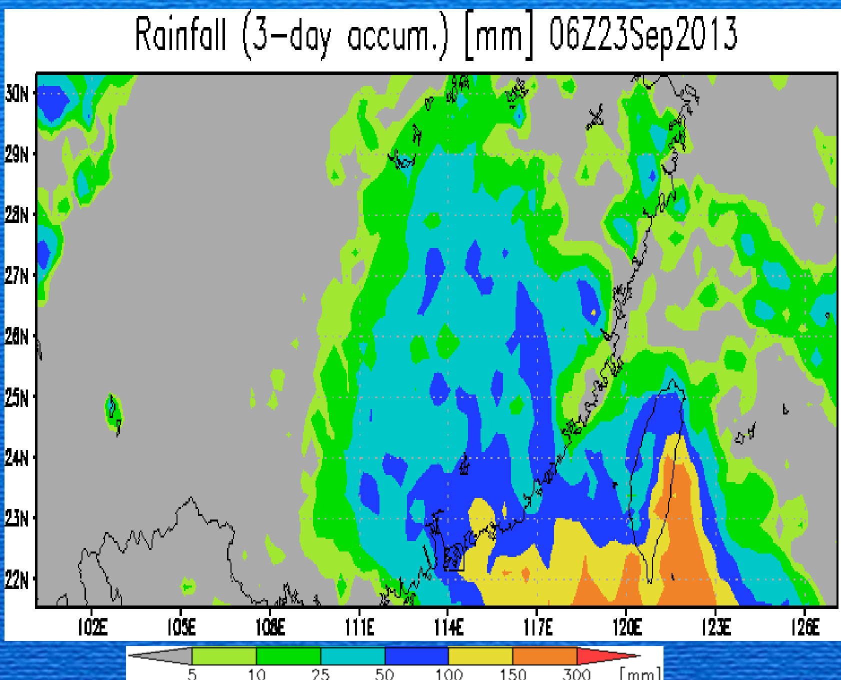

Thanks!

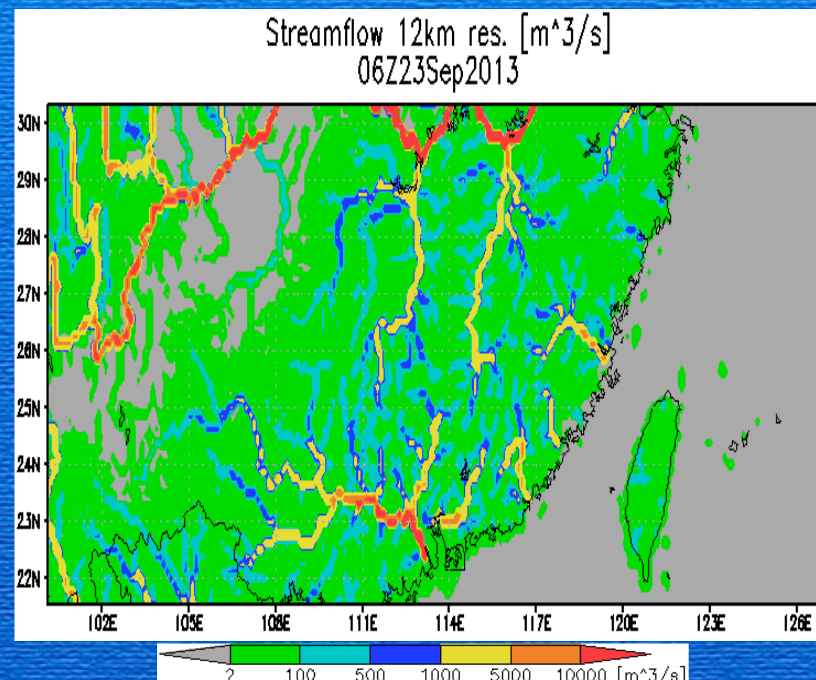


DRIVE Model
Precipitation
(TRMM, GPM, ...)
NowCast
Wind, Air T
(e.g. MERRA)
GEOS-5
ForeCast
Land Surface Model
(VIC)
Coupled
Runoff
DRTR Routing
Calibration
(SCE-UA)
Vegtation
(MODIS/UMD)
Soil
(e.g. FAO, VIC community)
DRT
Hydrography
(SRTM, HydroSHEDS)
Nested Run
Yes
Validation
Evaluation
Discharge, Velocity,
Stage, Inundation...
Flooding?
Population
Economics ...
(e.g. UN)
Yes
Gauge streamflow;
Satellite snow extent,
flood map and soil moisture;
Reported flood inventory...
(e.g. USGS, GRDC, MODIS, SMAP...)
Flood Damage
Social-economic impacts


Flood Detection/Intensity (depth above threshold [mm])
06Z23Sep2013
50N 40N 30N 20N 10N EQ 10S 20S 30S 40S 50S
120W 90W 60W 30W 0 30E 60E 90E 120E 150E 180
0 10 20 50 100 200 [mm]


Flood Detection/Intensity (depth above threshold [mm])
06Z23Sep2013
30N 29N 28N 27N 26N 25N 24N 23N 22N
102E 105E 108E 111E 114E 117E 120E 123E 126E
0 10 20 50 100 200 [mm]


Rainfall (3-day accum.) [mm] 06Z23Sep2013
30N 29N 28N 27N 26N 25N 24N 23N 22N
102E 105E 108E 111E 114E 117E 120E 123E 126E
5 10 25 50 100 150 300 [mm]


Streamflow 12km res. [m^3/s]
06Z23Sep2013
30N 29N 28N 27N 26N 25N 24N 23N 22N
102E 105E 108E 111E 114E 117E 120E 123E 126E
2 100 500 1000 5000 10000 [m^3/s]